AD

MEMORANDUM REPORT ARCCB-MR-94040

GEOMETRIC DIMENSIONING AND TOLERANCING - 1946 TO 1982 THE DIFFERENCES IN THE STANDARDS

DAVID H. HONSINGER

OCTOBER 1994

US ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
CLOSE COMBAT ARMAMENTS CENTER
BENÉT LABORATORIES
WATERVLIET, N.Y. 12189-4050

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

DISCLAIMER

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

The use of trade name(s) and/or manufacturer(s) does not constitute an official indorsement or approval.

DESTRUCTION NOTICE

For classified documents, follow the procedures in DoD 5200.22-M, Industrial Security Manual, Section II-19 or DoD 5200.1-R, Information Security Program Regulation, Chapter IX.

For unclassified, limited documents, destroy by any method that will prevent disclosure of contents or reconstruction of the document.

For unclassified, unlimited documents, destroy when the report is no longer needed. Do not return it to the originator.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1994	Final

4. TITLE AND SUBTITLE

GEOMETRIC DIMENSIONING AND TOLERANCING - 1946 TO 1982
THE DIFFERENCES IN THE STANDARDS

5. FUNDING NUMBERS

AMCMS No. 6126.24.H180.0
PRON No. W16H1F308

6. AUTHOR(S)

David H. Honsinger

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army ARDEC
Benet Laboratories, AMSTA-AR-CCB-O
Watervliet, NY 12189-4050

8. PERFORMING ORGANIZATION REPORT NUMBER

ARCCB-MR-94040

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army ARDEC
Close Combat Armaments Center
Picatinny Arsenal, NJ 07806-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

An analysis is made of the meaning of the symbolically represented characteristics defined in certain dimensioning and tolerancing standards, authorized for use by the Department of Defense and the U.S. Army in the preparation of engineering drawings. The analysis is based on a comparison of the defined meaning in each of these standards as it relates to the defined meaning in the most current standard. The results show that the meaning and the associated tolerance has, in some cases, changed significantly as the standards evolved. These differences are identified and described.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Geometric, Dimensioning, Tolerancing	29
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

TABLE OF CONTENTS

INTRODUCTION

The onset of World War II highlighted the need for a standardized method of dimensioning and tolerancing engineering drawings. Prior to that time, the design and manufacture of a component were largely conducted within the same organization, and communication between the design side of the business and the manufacturing side was an everyday occurrence. As a result, the functional relationships required between the various features of the component could be discussed in detail with the manufacturing personnel. When the finished drawings arrived in the shops, everyone involved in manufacturing the component(s) "knew what the drawings meant" and the manufactured parts "went together as designed," proving that the drawings were unambiguous. This misconception of unambiguity was painfully proven incorrect when, because of logistical requirements, additional sources were recruited to make parts to these same drawings. Parts that had been previously produced and assembled without problems no longer assembled. Drawings previously considered unambiguous now required "interpretation." Most of the problems were resolved by changing the manufacturing process, but the real problem had been exposed; the drawings were not unambiguous.

The solution to these problems was proposed by a method of dimensioning that employs symbols and identifies functional relationships to convey engineering intent. This type of dimensioning has been variously called datum dimensioning, true position tolerancing, and geometric dimensioning and tolerancing.

Over the years since World War II, the U.S. Army has invoked at least seven dimensioning and tolerancing standards in which datums and symbols are recommended for preparation of engineering drawings. These standards have evolved from simple, unsophisticated documents, in which the intent was to provide control of a characteristic as it was understood in the jargon of the day, to one in which the intent is to provide control of the characteristic as it is technically defined.

The objective of this work is not to interpret, but rather to draw attention to the differences between the standards in the defined meaning of a characteristic and its associated tolerance. This effort is necessary in light of recent Department of Defense mandates dealing with the revision of engineering drawings, which state that the revisions must be made in accordance with the standard in effect at the time of the creation of the original drawing. These mandates require knowledge of the meaning of each characteristic, as defined in the standard of the time, in terms of the current standard.

In the following sections, an explanation will be made of a characteristic control as indicated in the current standard. This will be followed by a similar explanation for the control as indicated in each of the previous standards. When the current standard addresses symbolic control of a characteristic and no identical control exists in a particular previous standard, such will be stated, unless that control can be provided by an extension of principle. When such extension of principle is made, it will be stated. Extension of principle is not allowed with military standards, therefore none will be made.

The final section addresses practices not in the current standard. When possible, a correlation will be drawn to the controls (symbols) in the current standard that provide the same degree of control as those no longer used.

CHARACTERISTIC: ANGULARITY

SYMBOL: ∠

CURRENT STANDARD: ANSI Y14.5M-1982

Angularity, as defined by the current standard, is a condition of a surface or axis at a specified angle (other than 90 degrees) from a datum plane or axis.

Angularity tolerances may be applied to surfaces or to features of size.

Angularity tolerances applied to surfaces are specified by directing a leader from the completed feature control frame to the surface being controlled.

Angularity tolerances applied to features of size are specified by associating a completed feature control frame with the dimension, stating the size of the feature being controlled.

Angularity tolerances applied to surfaces are always specified without material condition modifiers.

Angularity tolerances applied to features of size may include a material condition modifier. If no material condition modifier is specified, regardless of feature size (RFS) applies.

A datum reference is always indicated in the feature control frame.

ANSI Y14.5-1973

SYMBOL: ∠

Meaning and application: Same as ANSI Y14.5M-1982.

USASI Y14.5-1966

SYMBOL: ∠

Meaning and application: As defined by this standard, angularity is the condition of a surface or line which is at the specified angle (other than 90 degrees) from a datum plane or axis.

Angularity is specified as indicated in the current standard.

Angularity tolerance may also be specified in a carefully worded note added to the drawing.

MIL-STD-8C (1963)

SYMBOL: ∠

Meaning and application: Same as ANSI Y14.5M-1982.

Angularity, per this standard, is specified differently than in the current standard.

Angularity tolerances applied to surfaces are specified by attaching the completed feature control frame to an extension line of the surface being controlled.

Angularity tolerances applied to features of size are specified by attaching the completed feature control frame to the center line of the feature being controlled.

NOTE: When multiple features are constructed about the same center line to which an angularity tolerance has been applied, those features to which the tolerance applies should be identified, if the tolerance does not apply to all.

MIL-STD-8B (1959)

SYMBOL: ∠

Meaning and application: Same as MIL-STD-8C (1963).

MIL-STD-8A (1953)

SYMBOL: ∠

Meaning and application: Same as MIL-STD-8C (1963).

30-1-7 (1946)

SYMBOL: None

Meaning and application: This standard provides no means of symbolically specifying an angularity tolerance.

NOTE: This standard is truly unsophisticated, and even though the symbol used to describe a characteristic may be the same as is used in the current standard, the actual meaning or interpretation may be different. Prior to revising any drawing prepared to this standard, consideration should be given to replacing the existing document with one revised in accordance with the latest dimensioning and tolerancing standard.

CHARACTERISTIC: CIRCULARITY (ROUNDNESS)

SYMBOL: ○

CURRENT STANDARD: ANSI Y14.5M-1982

Circularity, as defined by the current standard, is a condition of a surface of revolution where:

1. For a cylinder or cone, all points of the surface intersected by any plane perpendicular to a common axis are equidistant from that axis.

2. For a sphere, all points of the surface intersected by any plane passing through a common center are equidistant from that center.

The value of the circularity tolerance specifies the radial difference in size of the two concentric circles that form the bounds of the tolerance zone. Each circular element of the controlled feature must lie within these bounds, and the tolerance applies independently at any plane described above. The circularity tolerance shall be less than the size tolerance except when applied to parts subject to free-state variation.

Circularity is specified by directing a leader from a complete feature control frame, to any line representing the surface to be controlled.

Circularity tolerances always apply RFS and no datum references are made.

ANSI Y14.5-1973

SYMBOL: ○

Meaning and application: Same as ANSI Y14.5M-1982.

USASI Y14.5-1966

SYMBOL: ○

Meaning and application: Same as ANSI Y14.5M-1982.

MIL-STD-8C-1966

SYMBOL: ○

Meaning and application: As defined in this standard, a roundness (circularity) tolerance is either the difference in the diameters of two concentric circles (in a plane normal to the axis) between which the surface so toleranced must lie, or the width of the annular zone between such concentric circles.

Roundness (circularity), as defined by this standard as opposed to the current standard, is by default the difference in diameter of the two concentric circles bounding the tolerance zone.

To specify roundness in accordance with this standard in such a manner as have the same meaning as the current standard, it is necessary to add "ON R" to the tolerance value.

Roundness applies RFS and is specified without datum reference.

MIL-STD-8B (1963)

SYMBOL: ○

Meaning and application: As defined by this standard, roundness (circularity) is the difference in the diameters of two concentric circles (in planes normal to the axis) between which the surfaces so toleranced must lie.

No method of application is allowed in this standard that would allow the value placed in the feature control frame to be interpreted as radial separation.

Roundness applies RFS and is specified without datum reference.

MIL-STD-8A (1959)

SYMBOL: None

Meaning and application: This standard provides no means of symbolically specifying a circularity tolerance. Roundness requirements shall be specified in a note added to the drawing.

30-1-7 (1946)

SYMBOL: None

Meaning and application: Same as MIL-STD-8A (1959).

NOTE: This standard is truly unsophisticated, and even though the symbol used to describe a characteristic may be the same as is used in the current standard, the actual meaning or interpretation may be different. Prior to revising any drawing prepared to this standard, consideration should be given to replacing the existing document with one revised in accordance with the latest dimensioning and tolerancing standard.

CHARACTERISTIC: CONCENTRICITY

SYMBOL: ◎

CURRENT STANDARD: ANSI Y14.5M-1982

Concentricity, as defined by the current standard, is a condition where the axes of all cross-sectional elements of a surface of revolution are common to the axis of a datum feature.

Concentricity verification requires determination of the centroid of the area at all cross sections of the controlled feature regardless of surface condition. This centroid must fall within the tolerance zone.

Irregularities in the form of the controlled feature may entail a time-consuming analysis in order to verify compliance with the concentricity requirements. Therefore, unless a definite need exists for the application of a concentricity control, it is recommended that coaxiality controls be specified in terms of runout or position tolerances.

Concentricity is specified by associating a completed feature control frame to a size dimension.

Concentricity applies RFS.

Concentricity tolerances always include a datum reference.

ANSI Y14.5-1973

SYMBOL: ◎

Meaning and application: Same as ANSI Y14.5M-1982.

USASI Y14.5-1966

SYMBOL: ◎

Meaning and application: Same as ANSI Y14.5M-1982.

MIL-STD-8C (1963)

SYMBOL: ●

Meaning and application: There are significant differences in the meaning of "concentricity" between this standard and the current standard. Concentricity, as defined in this standard, is a condition where two or more regular features (cylinders, cones, spheres, hexagons, etc.) in any combination have a common axis.

In application, the characteristic is more of a generic coaxiality control. Concentricity, as defined in the current standard, applies only RFS and may require detailed surface analysis to determine compliance with the requirements. Concentricity, as applied in this standard, is applicable on both an RFS and a maximum material condition (MMC) basis.

Applied on an RFS basis, concentricity per this standard, takes on the meaning of circular runout in the current standard.

Applied on an MMC basis, concentricity per this standard, is interpreted as position in the current standard.

Concentricity is specified by associating a completed feature control frame, including abbreviation TIR (total indicator runout) after the tolerance value, with the size dimension of the feature to be controlled.

Concentricity tolerances always contain a datum reference and may include material condition modifiers. RFS applies when no material condition modifier is specified.

MIL-STD-8B (1959)

SYMBOL: ◎

Meaning and application: Same as MIL-STD-8C (1963), with the exception that the datum axis may be the common axis implied by the drawing.

MIL-STD-8A (1953)

SYMBOL: ◎

Meaning and application: Same as MIL-STD-8C (1963).

30-1-7 (1946)

SYMBOL: ◎

Meaning and application: Same as MIL-8-C (1963), with the exception that the symbol is present in the feature control frame when the control is independent (RFS). Dependent/functional (MMC) is intended when the symbol does not appear in the feature control frame and is interpreted as position, MMC in the current standard.

NOTE: This standard is truly unsophisticated, and even though the symbol used to describe a characteristic may be the same as is used in the current standard, the actual meaning or interpretation may be different. Prior to revising any drawing prepared to this standard, consideration should be given to replacing the existing document with one revised in accordance with the latest dimensioning and tolerancing standard.

CHARACTERISTIC: CYLINDRICITY

SYMBOL: ⌭

CURRENT STANDARD: ANSI Y14.5M-1982

Cylindricity, as defined by the current standard, is a condition of a surface of revolution in which all points of the surface are equidistant from a common axis.

The value of the cylindricity tolerance specifies the radial difference in size between the two concentric cylinders that form the bounds of the tolerance zone. All elements of the controlled feature must lie within these bounds, and the tolerance applies simultaneously to both circular and longitudinal elements of the surface.

Cylindricity is specified by directing a leader from a completed feature control frame, to any line representing the controlled surface.

Cylindricity tolerances always apply RFS and no datum references are indicated in the feature control frame.

Cylindricity tolerance shall always be less than the size tolerance.

ANSI Y14.5-1973

SYMBOL: ⌭

Meaning and application: Same as ANSI Y14.5M-1982.

USASI Y14.5-1966

SYMBOL: ⌭

Meaning and application: Same as ANSI Y14.5M-1982.

MIL-STD-8C-1963

SYMBOL: None

Meaning and application: This standard provides no means of symbolically specifying a cylindricity tolerance. Cylindricity requirements shall be stated in a note added to the drawing.

MIL-STD-8B (1959)

SYMBOL: None

Meaning and application: Same as MIL-STD-8C (1963).

MIL-STD-8A (1953)

SYMBOL: None

Meaning and application: Same as MIL-STD-8C (1963).

30-1-7 (1946)

SYMBOL: None

Meaning and application: Same as MIL-STD-8B (1959).

NOTE: This standard is truly unsophisticated, and even though the symbol used to describe a characteristic may be the same as is used in the current standard, the actual meaning or interpretation may be different. Prior to revising any drawing prepared to this standard, consideration should be given to replacing the existing document with one revised in accordance with the latest dimensioning and tolerancing standard.

CHARACTERISTIC: FLATNESS

SYMBOL: ⏥

CURRENT STANDARD: ANSI Y14.5M-1982

Flatness is defined in the current standard as the condition of a surface having all elements in one plane.

Flatness tolerance applies to an area of a surface and as such, the tolerance may be specified as applying to the entire surface, or it may be specified as applying on a unit basis to control abrupt changes in relatively small areas.

Flatness tolerance on a unit basis may be applied either alone or in combination with flatness of the entire surface.

Flatness is specified by directing a leader from the completed feature control frame to the surface being controlled, in a view where the surface appears as a straight line.

Flatness tolerance is specified without material condition modifiers.

When the flatness tolerance is applied to a surface associated with a size dimension, the flatness tolerance shall be smaller than the size tolerance.

No datum references are specified.

ANSI Y14.5-1973

SYMBOL: ⏥

Meaning and application: Same as ANSI Y14.5M-1982.

USASI Y14.5-1966

SYMBOL: ⏥

Meaning and application: Same as ANSI Y14.5M-1982.

MIL-STD-8C (1963)

SYMBOL: —

Meaning and application: Same as ANSI Y14.5M-1982.

The method of specifying the flatness tolerance is to apply the completed feature control frame to an extension line of the surface being controlled.

NOTE: **ONLY** this standard states that a flatness tolerance may exceed the size tolerance, and only when the tolerance is applied in a sheet metal application.

MIL-STD-8B (1959)

SYMBOL: —

Meaning and application: Same as MIL-STD-8C (1963).

MIL-STD-8A (1953)

SYMBOL: ~

Meaning and application: Same as MIL-STD-8C (1963).

30-1-7 (1946)

SYMBOL: None

Meaning and application: This standard provides no means of symbolically specifying a flatness tolerance. Control of flatness is specified in a note applied to the drawing.

NOTE: This standard is truly unsophisticated, and even though the symbol used to describe a characteristic may be the same as is used in the current standard, the actual meaning or interpretation may be different. Prior to revising any drawing prepared to this standard, consideration should be given to replacing the existing document with one revised in accordance with the latest dimensioning and tolerancing standard.

CHARACTERISTIC: PARALLELISM

SYMBOL: //

CURRENT STANDARD: ANSI Y14.5M-1982

Parallelism, as defined by the current standard, is the condition of a surface equidistant at all points from a datum plane or an axis equidistant along its length to a datum axis.

Parallelism, as control of a surface, is specified by directing a leader from a completed feature control frame to a line representing the feature to be controlled.

Parallelism, as control of an axis, is specified by associating a completed feature control frame with the size dimension of the feature being controlled.

Parallelism tolerances, applied to a surface, are specified without material condition modifiers.

Parallelism tolerances, specified for a feature of size, may indicate a material condition modifier.

As an extension of principle, parallelism tolerances may be applied to noncircular features, such as key slots.

ANSI Y14.5-1973

SYMBOL: //

Meaning and application: Same as ANSI Y14.5M-1982.

USASI Y14.5-1966

SYMBOL: ||

Meaning and application: Same as ANSI Y14.5M-1982.

MIL-STD-8C (1963)

SYMBOL: ||

Meaning and application: Same as ANSI Y14.5M-1982.

MIL-STD-8B (1959)

SYMBOL: ||

Meaning and application: Same as ANSI Y14.5M-1982.

MIL-STD-8A (1953)

SYMBOL: ||

Meaning and application: Parallelism tolerances specified in accordance with this standard are considered to be independent geometric controls and as such apply RFS.

30-1-7 (1946)

SYMBOL: ||

Meaning and application: As indicated by this standard, the application of a parallelism tolerance indicates that the entire surface thus designated must be parallel to the datum surface within the tolerance specified.

Parallelism as applied in this standard is considered to be either an independent geometric control, in which case it applies RFS to both the controlled feature and any datum reference, or a dependent/functional geometric control, in which case it applies at MMC.

Parallelism tolerance as an independent (RFS) control of a feature is applied by attaching a feature control frame containing the parallelism symbol, a datum reference, and a tolerance value to an extension line of the feature being controlled.

Parallelism tolerance as an independent (RFS) control of an axis is specified by associating a feature control frame containing the parallelism symbol, a datum reference, and a tolerance value to the size of the feature being controlled.

Parallelism tolerance as a dependent (MMC) control is specified by associating a feature control frame containing only a datum reference and a tolerance value to the dimension, indicating the size of the feature being controlled.

NOTE 1: The standard indicates that the method used to specify dependent parallelism is also the same method used to indicate dependent perpendicularity and what the standard refers to as dependent symmetry and concentricity. An analysis of the geometry of the component is, therefore, necessary in order to determine the characteristic being controlled. In any case, dependent tolerances apply at MMC for both the controlled feature and the datum feature, when applicable.

NOTE 2: This standard is truly unsophisticated, and even though the symbol used to describe a characteristic may be the same as is used in the current standard, the actual meaning or interpretation may be different. Prior to revising any drawing prepared to this standard, consideration should be given to replacing the existing document with one revised in accordance with the latest dimensioning and tolerancing standard.

CHARACTERISTIC: PERPENDICULARITY

SYMBOL: ⊥

CURRENT STANDARD: ANSI Y14.5M-1982

Perpendicularity, as defined by this standard, is the condition of a surface, median plane, or axis at a right angle to a datum plane or axis.

Perpendicularity tolerances applied to surfaces are specified by attaching the completed feature control frame to an extension line of the surface being controlled, or by directing a leader from the completed feature control frame to the surface being controlled.

Perpendicularity tolerances applied to features of size are specified by associating the completed feature control frame to the size dimension of the feature being controlled.

Perpendicularity tolerances applied to surfaces are specified without material condition modifiers.

Perpendicularity tolerances applied to features of size may include a material condition modifier.

Perpendicularity tolerances always include a datum reference.

ANSI Y14.5-1973

SYMBOL: ⊥

Meaning and application: Same as ANSI Y14.5M-1982.

USASI Y14.5-1966

SYMBOL: ⊥

Meaning and application: Same as ANSI Y14.5M-1982.

MIL-STD-8C (1963)

SYMBOL: ⊥

Meaning and application: Perpendicularity, as defined in this standard, is the condition of a surface or axis which is at exactly 90 degrees from a datum plane or datum axis.

Perpendicularity tolerances applied to surfaces are specified by attaching the completed feature control frame to an extension line of the feature to be controlled.

Perpendicularity tolerances applied to axes are specified by associating the completed feature control frame to the size dimension of the feature being controlled.

Specifying a perpendicularity tolerance to a circular feature relative to a planar datum surface creates a cylindrical tolerance, within which the controlled feature axis shall lie.

Specifying a perpendicularity tolerance to a circular feature relative to a circular datum feature creates a tolerance zone bounded by two planes, at right angles to the datum axis and separated by the value of the stated tolerance. The axis of the controlled feature shall lie between these two planes.

Perpendicularity tolerances applied to surfaces are specified without material condition modifiers.

Perpendicularity tolerances controlling features of size may include a material condition modifier.

Perpendicularity tolerances always include a datum reference.

MIL-STD-8B (1963)

SYMBOL: ⊥

Meaning and application: Same as MIL-STD-8C (1966).

MIL-STD-8A (1959)

SYMBOL: ⊥

Meaning and application: Perpendicularity, as defined in this standard, is the tolerance governing the perpendicularity of surfaces, axes, and axial planes with relation to each other.

Perpendicularity as applied in this standard is considered an independent geometric control and as such, applies RFS at all times.

Perpendicularity tolerances applied to surfaces are specified by attaching the completed feature control frame to an extension line of the feature being controlled.

Perpendicularity tolerances applied to axes and median planes are specified by associating the completed feature control frame to the size dimension of the feature being controlled.

Perpendicularity tolerances always include a datum reference.

30-1-7 (1946)

SYMBOL: ⊥

Meaning and application: As indicated by this standard, the application of a perpendicularity tolerance requires that the entire surface so designated (controlled surface) must be perpendicular to the datum surface within the total variation indicated.

Perpendicularity as applied in this standard is considered to be either an independent geometric control, in which case it applies RFS for both the controlled feature and any referenced datum feature, or a dependent/ functional geometric control, in which case it applies at MMC.

Perpendicularity tolerance as an independent (RFS) control is specified by attaching a feature control frame containing the perpendicularity symbol, a datum reference, and a tolerance value to an extension line of the feature being controlled.

Perpendicularity tolerance as a dependent (MMC) control is specified by associating a feature control frame containing only a datum reference and a tolerance value, with the dimension indicating the size of a feature.

NOTE 1: The standard indicates that the method used to specify dependent perpendicularity is also the same method used to indicate dependent parallelism and what the standard refers to as dependent symmetry and concentricity. An analysis of the geometry of the component is, therefore, necessary in order to determine the characteristic being controlled.

NOTE 2: This standard is truly unsophisticated, and even though the symbol used to describe a characteristic is the same as is used in the current standard, the actual meaning or interpretation may be different, since the definitions of the terms are applied at their broadest meaning. Prior to revising drawings prepared to this standard, consideration should be given to replacing the existing document with one revised in accordance with the latest dimensioning and tolerancing standard.

CHARACTERISTIC: POSITION

SYMBOL: ⊕

CURRENT STANDARD: ANSI Y14.5M-1982

Position tolerance, as stated in this standard, defines a zone within which the center, axis, or center plane of a feature of size is permitted to vary from true (theoretically exact) position.

Position tolerance is specified by associating the completed feature control frame with the size dimension of the feature(s) being controlled.

Position tolerance specification always includes a datum reference(s) in the feature control frame.

Material condition modifiers shall always be specified for both the tolerance and datum references, as applicable. Failure to specify applicable material condition modifiers yields incomplete drawings.

ANSI Y14.5-1973

SYMBOL: ⊕

Meaning and application: Same as ANSI Y14.5M-1982 with the exceptions that:

1. The specification of a material condition modifier is not mandatory in the feature control frame. In the absence of a material condition modifier, MMC is implied.

2. The characters in the feature control frame are sequenced differently. The sequence indicated in this standard is:

    a. Geometric characteristic

    b. Datum reference(s)

    c. Tolerance value

The sequence specified in ANSI Y14.5M-1982 (geometric characteristic, tolerance, datum reference(s)), referred to in this (1973) standard as the international sequence, is permitted.

3. In addition to composite positional tolerances as applied in accordance with ANSI Y14.5M-1982, where the controlled feature is required to simultaneously satisfy both the pattern locating requirements and the feature locating requirements, this standard allows combination position and plus/minus tolerancing. In the latter, the axis of each feature can lie outside its respective coordinate tolerance zone by an amount equal to one-half the specified position tolerance when the feature is produced at its specified material condition.

USASI Y14.5-1966

SYMBOL: ⊕

Meaning and application: Many differences exist between this standard and ANSI Y14.5M-1982.

1. Identification of the tolerance zone is mandatory. Identification is accomplished by adding the abbreviation DIA, the word TOTAL, or the letter R in the feature control frame, immediately after the tolerance value. These (DIA, TOTAL, R) result in the following:

   a. Specifying DIA after the tolerance indicates a cylindrical tolerance zone whose diameter is equal to the tolerance value. DIA applies to circular features.

   b. Specifying TOTAL after the tolerance indicates a tolerance zone existing between two planes, separated by a distance equal to the tolerance, and equally distributed about the basic location. TOTAL applies to noncylindrical features.

   c. R may be indicated for both circular and noncircular features, and results in either:

      - A cylindrical tolerance zone whose radius is equal to the tolerance value when indicated in a feature control frame applied to a circular part, or

      - A tolerance zone existing between two planes, separated by a distance equal to twice the tolerance value, and equally distributed about the basic location when indicated in a feature control frame applied to a noncircular part.

2. Specification of a material condition modifier is not mandatory. Failure to indicate a material condition modifier implies MMC.

3. Only M (maximum material condition) and S (regardless of feature size) material condition modifiers are applicable.

4. Three methods of specifying datum reference(s) are allowed:

   a. By inclusion of the datum feature identifier in the feature control frame.

   b. By implication indicating with basic dimensions, the location from a surface to the feature(s) being controlled, or by implication when there is only a single feature that could be a datum (for example, coaxial features).

   c. By specifying a minimum edge distance (indicated as being especially suitable for cast or forged parts).

5. Combination tolerancing (coordinate, plus/minus dimensions, and position tolerancing) may be applied to locate patterns of features where the pattern-location tolerance is greater than the feature-relating tolerance. The coordinate dimensions serve as the pattern-locating dimensions and the basic dimensions are the feature-relating dimensions. Tolerancing applied in this manner allows the axis of the controlled feature to lie outside of its respective coordinate tolerance zone by an amount equal to one-half the specified positional tolerance when the feature is at its specified material condition.

NOTE: Tolerancing may be applied in accordance with this standard, which effectively creates the requirement that the axes of each feature in a pattern of features must simultaneously fall within both the pattern- locating tolerance zone and the feature-relating tolerancing zone. This is accomplished by locating one of the features in the pattern by coordinate dimensions and identifying that feature as a datum. The remaining features in the pattern are then located by basic dimensions from that datum feature, and controlled with a position tolerance indicating the identified feature as a datum reference in the feature control frame.

MIL-STD-8C (1963)

SYMBOL: ⊕

Meaning and application: Same as USASI Y14.5-1966 with the exception that "R" is not allowed to identify the tolerance zone shape.

MIL-STD-8B (1959)

SYMBOL: ⊕

Meaning and application: Same as MIL-STD-8C (1963).

MIL-STD-8A (1953)

SYMBOL: ⊕

Meaning and application: This standard indicates that position tolerance is an axis control. Since extension of principles stated in military standards is not allowed, application of position tolerances to features not constructed about an axis is prohibited.

Material condition is not addressed in this standard, therefore position tolerances apply RFS.

The abbreviation "DIA" shall appear in the feature control frame after the tolerance value.

30-1-7 (1946)

SYMBOL: None

Meaning and application: The meaning and application of position tolerance in this standard is not easily related to the current standard.

Paraphrased, the standard states relative to position, that when a feature control frame containing only a datum reference and a tolerance value (no characteristic symbol) is applied, the entire surface, form, or group designated must be positioned within a total functional variation (MMC) equal to the tolerance value with respect to the datum.

Again paraphrased, the standard also states that when a feature control frame containing a value only (no datum reference and no characteristic symbol) is applied, the entire surface, form, or group thus designated must be positioned within a total functional variation (MMC) equal to the tolerance value with respect to the basic locational dimensions.

The standard, as written, is ambiguous with a position tolerance specified in two manners:

1. Associating a feature control frame, containing a tolerance value only, to a feature of size. The intent of this application is to serve as a "feature-relating" tolerance for a pattern of features.

2. Associating a feature control frame, containing a datum reference and a tolerance value only, to a feature of size. Application according to this method requires analysis of the part geometry, since this application also controls that which the standard refers to as "functional concentricity, symmetry, perpendicularity, and parallelism."

NOTE: This standard is truly unsophisticated. Prior to revising any drawing prepared to this standard, consideration should be given to replacing the existing document with one revised to be in compliance with the latest standard.

CHARACTERISTIC: PROFILE

CURRENT SYMBOLS:

PROFILE OF A SURFACE: ⌓

PROFILE OF A LINE: ⌒

CURRENT STANDARD: ANSI Y14.5M-1982

Profile, as defined in this standard, is the outline of an object in a given plane (two-dimensional figure).

Profile tolerance may be applied either to an entire surface (resulting in a three-dimensional tolerance zone) or to individual profiles (lines) taken at various cross sections through the part (resulting in a two- dimensional tolerance zone). The specification of the desired control is made by use of the appropriate symbol.

The tolerance zone associated with profile tolerance may be applied in three ways: unilaterally, uniform bilaterally, and nonuniform bilaterally. Uniform bilateral tolerance applies unless indicated otherwise.

Profile tolerances establish boundaries that follow the geometric shape of the true (specified) profile.

Profile tolerances are measured normal to the true profile.

All deviations from true profile must blend.

Profile tolerances are specified by directing a leader from a completed feature control frame to the surface being controlled, in a view where the true profile is specified.

Unilateral profile tolerance distribution is indicated by including a chain line, drawn parallel to the true profile, on the side of the profile to which the tolerance applies. Dimension lines are added indicating that the tolerance applies unilaterally. One end of a dimension line is extended to the completed feature control frame.

Nonuniform bilateral tolerance distribution is specified by including a chain line on each side of the true profile and dimensioning either or both tolerance widths with basic dimensions. One end of a dimension line is extended to the completed feature control frame.

Profile tolerance may or may not include a datum reference in the feature control frame.

Profile tolerances specified without datum references indicate that the tolerance applies to a true geometric representation of the controlled surface.

ANSI Y14.5-1973

SYMBOLS:

PROFILE OF A SURFACE: ⌓

PROFILE OF A LINE: ⌒

Meaning and application: Same as ANSI Y14.5M-1982.

USASI Y14.5 1966

PROFILE OF A SURFACE: ⌓

PROFILE OF A LINE: ⌒

Meaning and application: Same as ANSI Y14.5M-1982, with the additional requirement that the distribution of the tolerance zone must also be indicated whether it be unilateral distribution, uniform, or non-uniform bilateral disposition. The method of specifying the disposition of the tolerance zone is the same as indicated for ANSI Y14.5M-1982.

MIL-STD-8C (1963)

SYMBOL: None

Meaning and application: This standard provides no means of symbolically specifying a profile tolerance. However, it does address "zone tolerances for contours." In application, "zone tolerance for contours" is a surface control comparable to profile tolerance in the current standard.

"Zone tolerance for contours" is specified in the same manner in which profile tolerance is specified according to USASI Y14.5-1966, with the exception that the leader is directed to the feature being controlled from a note indicating the tolerance. The note indicates whether the tolerance applies "all around" or "between locations."

"Zone tolerance for contours" requires that the distribution of the tolerance zone be indicated.

NOTE: Caution should be exercised when specifying "zone tolerance for contours" tolerances to this standard, since the standard indicates that the tolerance is specified to implied datums.

MIL-STD-8B (1959)

SYMBOL: None

Meaning and application: Same as MIL-STD-8C (1963).

MIL-STD-8A (1953)

SYMBOL: None

Meaning and application: This standard provides no means of symbolically specifying a profile tolerance. However, it does address "control of composite curved surfaces." In application, "control of composite curved surfaces" is a surface control comparable to profile tolerance in the current standard.

Two methods of defining the profile of the surface are indicated:

1. The offset method, in which the profile of the surface to be controlled is specified by indicating the "X" and "Y" coordinates of the surface to be controlled.

2. The radius method, in which the radius of all of the arcs that combine to form the curve and the dimensions necessary to locate the center points of those radii are specified.

The tolerance is specified as follows:

1. For a bilateral distribution of tolerance:

    a. A chain line is drawn on both sides of the profile to be controlled.

b. The width of the tolerance zone on either side of the controlled surface is dimensioned.

c. The total width of the tolerance zone is dimensioned in a note of stating, ".XXX TOL ZONE FOR PROFILE." A leader is directed from the note to the surface being controlled.

2. For a unilateral distribution of tolerance:

a. A chain line is drawn on the side of the controlled surface on which the tolerance is to apply.

b. The width of the tolerance zone is dimensioned. The value specified may be signed (+/-) as a further indication of the direction of tolerance application.

30-1-7 (1946)

SYMBOL: None

Meaning and application: This standard provides no method of specifying a profile tolerance.

NOTE: This standard is truly unsophisticated, and even though the symbol used to describe a characteristic may be the same as is used in the current standard, the actual meaning or interpretation may be different. Prior to revising any drawing prepared to this standard, consideration should be given to replacing the existing document with one revised in accordance with the latest dimensioning and tolerancing standard.

CHARACTERISTIC: RUNOUT

SYMBOLS:

CIRCULAR RUNOUT: ↗

TOTAL RUNOUT: ↗↗

CURRENT STANDARD: ANSI Y14.5M-1982

Runout, as defined by the current standard, is a composite tolerance used to control the functional relationship of one or more features of a part to a datum axis.

Runout may be specified in two forms:

1. Circular runout, which provides for control of circular elements of a surface.

2. Total runout, which provides control of all the surface elements of the controlled feature.

Circular runout tolerances apply independently at each circular element location and allow rezeroing the measuring device for each location tested in the verification process.

Total runout tolerances apply simultaneously at all elements of the surface being controlled and do not allow rezeroing the measuring device during the verification process.

Runout tolerance is specified by directing a leader from a completed feature control frame to the surface being controlled.

Runout tolerances apply RFS.

Runout tolerances always indicate a datum reference.

Runout tolerances apply normal to the true geometric shape.

ANSI Y14.5-1973

SYMBOL: ↗

Meaning and application: Same as ANSI Y14.5M-1982, with the exception that only one symbol is used. Total runout is specified by adding the word "total" beneath the feature control symbol. Circular runout applies if "total" is not added under the feature control frame.

USASI Y14.5-1966

SYMBOL: ↗

Meaning and application: Same as ANSI Y14.5M-1982, with the exception that only one symbol is used. Circular runout is specified by adding the word "circular" beneath the feature control symbol. Total runout applies if "circular" is not added under the feature control frame.

MIL-STD-8C (1963)

SYMBOL: None

Meaning and application: This standard provides no method of symbolically specifying a runout tolerance.

MIL-STD-8B (1959)

SYMBOL: None

Meaning and application: This standard provides no method of symbolically specifying a runout tolerance.

MIL-STD-8A (1953)

SYMBOL: None

Meaning and application: This standard provides no method of symbolically specifying a runout tolerance.

30-1-7 (1946)

SYMBOL: None

Meaning and application: This standard provides no method of symbolically specifying a runout tolerance.

NOTE: This standard is truly unsophisticated, and even though the symbol used to describe a characteristic may be the same as is used in the current standard, the actual meaning or interpretation may be different. Prior to revising any drawing prepared to this standard, consideration should be given to replacing the existing document with one revised in accordance with the latest dimensioning and tolerancing standard.

CHARACTERISTIC: STRAIGHTNESS

SYMBOL: —

CURRENT STANDARD: ANSI Y14.5M-1982

Straightness, as defined by the current standard, is the condition where an element of a surface or an axis is a straight line.

Straightness may be applied on a total length basis or on a unit length basis. Applying straightness on a unit basis is a means of controlling abrupt surface variations in a relatively short length.

Straightness tolerance on a unit basis may be applied alone or in combination with straightness for the entire length of the feature.

An extension of principle is stated in the current standard, whereby the application of a straightness tolerance to noncylindrical features is allowed. As a surface control, therefore, a straightness tolerance may be applied to any surface that is nominally straight. This includes inclined planes and uniform conical sections.

To specify straightness of a surface element, a view is selected in which the element appears as a straight line, and a leader line is drawn from the feature control frame, which contains the straightness symbol and tolerance, to the surface element to be controlled. No material condition modifiers are specified.

When applied as an axis control, the feature control frame containing the straightness symbol and tolerance is placed with the size dimension. Material condition modifiers are allowed when straightness of an axis control is indicated. The absence of a modifier implies RFS.

No datum references are stated when applying a straightness tolerance.

ANSI Y14.5 1973

SYMBOL: —

Meaning and application: Same as ANSI Y14.5M-1982.

USASI Y14.5 1966

SYMBOL: —

Meaning and application: Straightness, as defined in this standard, is a condition where an element of a surface is a straight line.

There is no provision in the standard to allow the application of the tolerance to an axis, and straightness tolerances are applied only to surface characteristics (elements).

While the standard does not specifically address the application of straightness on a unit basis, such may be done as an extension of principle. Applying straightness tolerances on both a total length basis and unit basis requires the use of two complete feature control frames.

MIL-STD-8C (1963)

SYMBOL: —

Meaning and application: Straightness of an axis, as defined in this standard, is the condition in which the axis does not deviate from a straight line. Straightness of the elements of a cylindrical or conical surface, as defined in this standard, is the condition in which no element deviates from a straight line.

This standard does not indicate that straightness tolerances are applicable to other than cylindrical or conical features.

Since this is a military standard, no expansion may be made and the extension of principle permitting application to any configuration other than that stated is not allowed.

Straightness of axis tolerances is applied by directing a leader from a completed feature control frame to the center line. NOTE: When multiple feature are constructed about the same center line to which a straightness tolerance has been applied, those features to which the tolerance applies should be identified.

Surface element control is specified by directing a leader from a completed feature control frame to the surface element being controlled.

Contrary to current standard practice, which does not allow for the application of material condition modifiers to surface tolerances, this standard illustrates the use of a material condition modified (MMC) straightness tolerance directed to a surface. This application is interpreted in the standard, and equates to the current application of specifying straightness at MMC and associating the feature control frame to the size dimension.

MIL-STD-8B (1959)

SYMBOL: —

Meaning and application: Straightness of axis of a figure of revolution, as defined in this standard, is the condition in which the axis does not deviate from a straight line. Straightness of the axis of a figure having a rectangular cross section, as defined in this standard, is the condition in which the axis is a plane.

Straightness tolerances are specified as indicated for MIL-STD-8C (1963).

MIL-STD-8A (1953)

SYMBOL: —

Meaning and application: Straightness, as defined in this standard, is the tolerance governing the straightness of an axis or axial plane.

There is no provision in this standard for the application of straightness to a surface element.

MIL-STD-8A refers to tolerances as being independent. The interpretation of this term equates to RFS in the current standard.

Straightness tolerance is specified by attaching the feature control frame to the size dimension of the feature being controlled.

30-1-7 (1946)

SYMBOL: None

Meaning and application: This standard provides no means of symbolically specifying a straightness tolerance.

NOTE: This standard is truly unsophisticated, and even though the symbol used to describe a characteristic may be the same as is used in the current standard, the actual meaning or interpretation may be different. Prior to revising any drawing prepared to this standard, consideration should be given to replacing the existing document with one revised in accordance with the latest dimensioning and tolerancing standard.

PAST PRACTICES

SYMMETRY

Though the definition of symmetry stated in each of the standards may be academically correct, each implies that a position tolerance, applied RFS, provides equivalent control. Each also implies that the use of a symmetry symbol is simply a matter of preference. Discretion should, therefore, be exercised when specifying symmetry to these standards.

ANSI Y14.5 1973

SYMBOL: ⌯

Symmetry, as defined in this standard, is a condition in which a feature (or features) is symmetrically disposed about the center plane of a datum feature.

Compliance of symmetry requirements is verified by determining the location of the center plane of the controlled feature relative to the datum plane. The center plane of the controlled feature shall fall within the specified tolerance limits.

Symmetry tolerances are applied by associating a completed feature control frame with the size dimension of the controlled feature.

Symmetry tolerances apply RFS and always contain a datum reference.

Symmetry and position tolerances applied RFS are illustrated in the standard as being interpreted identically.

USASI Y14.5 1966

SYMBOL: ⌯

Symmetry, as defined in this standard, is a condition wherein a part or a feature has the same contour and size on opposite sides of a central plane, or a condition in which a feature is symmetrically disposed about the central plane of a datum feature.

Meaning and application: Same as ANSI Y14.5-1973.

MIL-STD-8C (1963)

SYMBOL: ⌯

Symmetry, as defined in this standard, is a condition in which a part or feature has the same contour on opposite sides of a central plane.

Meaning and application: Same as ANSI Y14.5-1973.

MIL-STD-8B (1959)

SYMBOL: ≡

Symmetry, as defined in this standard, is a condition in which a part or feature has the same contour on opposite sides of a central plane, or a condition in which a feature has a common plane with a datum feature.

Meaning and application: Same as ANSI Y14.5-1973.

30-1-7 (1946)

SYMBOL: ℄

Symmetry, as specified in this standard, applies RFS and requires that a feature controlled by a symmetry tolerance must be symmetrical or central to the datum feature.

Meaning and application: Same as ANSI Y14.5 1973.

INTERRELATED GEOMETRIC CHARACTERISTICS

Interrelated geometric characteristics is not a single, defined characteristic control. It is rather an early version of a multiple feature control frame. When applied, all symbols and datum references appeared in a single, undivided feature control frame.

The use of multiple geometric symbols in a single feature control frame to create an interrelated geometric control was recommended in all of the military standards for those cases when it was necessary to control the geometrical accuracy of a feature by means of different tolerances, as follows:

1. Both (or all) characteristics governed by a single tolerance value;

2. Each characteristic related to a different datum; or

3. Characteristics intended for a simultaneous check of both (or all) geometric requirements.

In specifying interrelated geometric tolerances, the geometric characteristics with their respective datum references and the single tolerance value are shown in the same feature control frame.

A common example of the application of interrelated geometric tolerance occurs when a hole is located about a datum axis and is required to be perpendicular to a datum plane. In this example, two symbols (concentricity and perpendicularity) and two datum references (one for the feature establishing the axis and one for the feature establishing the plane) would appear in the feature control frame along with the tolerance value.

The most frequently used pairs of symbols are concentricity and perpendicularity.

NOTE: It must be remembered that concentricity as defined in these standards is NOT the same as concentricity as defined in the current standard.

This tolerancing method evolved, first, to one in which the single feature control frame was replaced with multiple feature control frames, specifying different datum references, and then again back to a single feature control frame invoking a single characteristic control. In the first step of the evolution, the concentricity symbol was generally replaced with a runout symbol in the upper feature control frame, while the perpendicularity symbol was indicated in the lower feature control frame. In the second phase, both symbols were replaced by a single (usually position) symbol, and the datum references were specified in the proper order of precedence.

Caution should be exercised when applying interrelated geometric characteristic controls, since one of the intentions of specifying the control is to indicate that all of the requirements are to exist simultaneously, but no provision is made in the standards to indicate the order of precedence of the datum references.

TECHNICAL REPORT INTERNAL DISTRIBUTION LIST

	NO. OF COPIES
CHIEF, DEVELOPMENT ENGINEERING DIVISION	
ATTN: SMCAR-CCB-DA	1
-DC	1
-DI	1
-DR	1
-DS (SYSTEMS)	1
CHIEF, ENGINEERING DIVISION	
ATTN: SMCAR-CCB-S	1
-SD	1
-SE	1
CHIEF, RESEARCH DIVISION	
ATTN: SMCAR-CCB-R	2
-RA	1
-RE	1
-RM	1
-RP	1
-RT	1
TECHNICAL LIBRARY	
ATTN: SMCAR-CCB-TL	5
TECHNICAL PUBLICATIONS & EDITING SECTION	
ATTN: SMCAR-CCB-TL	3
OPERATIONS DIRECTORATE	
ATTN: SMCWV-ODP-P	1
DIRECTOR, PROCUREMENT & CONTRACTING DIRECTORATE	
ATTN: SMCWV-PP	1
DIRECTOR, PRODUCT ASSURANCE & TEST DIRECTORATE	
ATTN: SMCWV-QA	1

NOTE: PLEASE NOTIFY DIRECTOR, BENÉT LABORATORIES, ATTN: SMCAR-CCB-TL OF ADDRESS CHANGES.

TECHNICAL REPORT EXTERNAL DISTRIBUTION LIST

	NO. OF COPIES
ASST SEC OF THE ARMY RESEARCH AND DEVELOPMENT ATTN: DEPT FOR SCI AND TECH THE PENTAGON WASHINGTON, D.C. 20310-0103	1
ADMINISTRATOR DEFENSE TECHNICAL INFO CENTER ATTN: DTIC-FDAC CAMERON STATION ALEXANDRIA, VA 22304-6145	12
COMMANDER U.S. ARMY ARDEC	
ATTN: SMCAR-AEE	1
SMCAR-AES, BLDG. 321	1
SMCAR-AET-O, BLDG. 351N	1
SMCAR-FSA	1
SMCAR-FSM-E	1
SMCAR-FSS-D, BLDG. 94	1
SMCAR-IMI-I, (STINFO) BLDG. 59 PICATINNY ARSENAL, NJ 07806-5000	2
DIRECTOR U.S. ARMY RESEARCH LABORATORY ATTN: AMSRL-DD-T, BLDG. 305 ABERDEEN PROVING GROUND, MD 21005-5066	1
DIRECTOR U.S. ARMY RESEARCH LABORATORY ATTN: AMSRL-WT-PD (DR. B. BURNS) ABERDEEN PROVING GROUND, MD 21005-5066	1
DIRECTOR U.S. MATERIEL SYSTEMS ANALYSIS ACTV ATTN: AMXSY-MP ABERDEEN PROVING GROUND, MD 21005-5071	1
COMMANDER ROCK ISLAND ARSENAL ATTN: SMCRI-ENM ROCK ISLAND, IL 61299-5000	1
MIAC/CINDAS PURDUE UNIVERSITY P.O. BOX 2634 WEST LAFAYETTE, IN 47906	1
COMMANDER U.S. ARMY TANK-AUTMV R&D COMMAND ATTN: AMSTA-DDL (TECH LIBRARY) WARREN, MI 48397-5000	1
COMMANDER U.S. MILITARY ACADEMY ATTN: DEPARTMENT OF MECHANICS WEST POINT, NY 10966-1792	1
U.S. ARMY MISSILE COMMAND REDSTONE SCIENTIFIC INFO CENTER ATTN: DOCUMENTS SECTION, BLDG. 4484 REDSTONE ARSENAL, AL 35898-5241	2
COMMANDER U.S. ARMY FOREIGN SCI & TECH CENTER ATTN: DRXST-SD 220 7TH STREET, N.E. CHARLOTTESVILLE, VA 22901	1
COMMANDER U.S. ARMY LABCOM MATERIALS TECHNOLOGY LABORATORY ATTN: SLCMT-IML (TECH LIBRARY) WATERTOWN, MA 02172-0001	2
COMMANDER U.S. ARMY LABCOM, ISA ATTN: SLCIS-IM-TL 2800 POWER MILL ROAD ADELPHI, MD 20783-1145	1

NOTE: PLEASE NOTIFY COMMANDER, ARMAMENT RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER, U.S. ARMY AMCCOM, ATTN: BENÉT LABORATORIES, SMCAR-CCB-TL, WATERVLIET, NY 12189-4050 OF ADDRESS CHANGES.

TECHNICAL REPORT EXTERNAL DISTRIBUTION LIST (CONT'D)

	NO. OF COPIES
COMMANDER U.S. ARMY RESEARCH OFFICE ATTN: CHIEF, IPO P.O. BOX 12211 RESEARCH TRIANGLE PARK, NC 27709-2211	1
DIRECTOR U.S. NAVAL RESEARCH LABORATORY ATTN: MATERIALS SCI & TECH DIV	1
CODE 26-27 (DOC LIBRARY) WASHINGTON, D.C. 20375	1
COMMANDER AIR FORCE ARMAMENT LABORATORY ATTN: AFATL/MN EGLIN AFB, FL 32542-5434	1
COMMANDER AIR FORCE ARMAMENT LABORATORY ATTN: AFATL/MNF EGLIN AFB, FL 32542-5434	1

NOTE: PLEASE NOTIFY COMMANDER, ARMAMENT RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER, U.S. ARMY AMCCOM, ATTN: BENÉT LABORATORIES, SMCAR-CCB-TL, WATERVLIET, NY 12189-4050 OF ADDRESS CHANGES.